The CREATION Scene-Generation Program Applied to Battlespace Flight Scenarios

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Abstract

The CREATION (Computer generation of Realistic Environments with Atmosphere for Thermal Imagery with Optics and Noise) scene-simulation program produces high-quality, realistic, 3-dimensional battlefield environments suitable for simulating battlefield flight scenarios. CREATION simulates detailed scene geometries based on actual geographical locations using Defense Mapping Agency (DMA) Digital Terrain Elevation Data (DTED) with dynamic targets and sensor platforms controlled in all six degrees of freedom. Target signatures and background component temperature are predicted by existing thermal prediction models using actual meteorological and environmental input data. The weather data may also be used to simulate LOWTRAN-equivalent atmospheric transmission and accurate battlefield obscurant effects. The CREATION program suite includes a feature editor to digitally map scene components. The CREATION scene simulator also includes a state-of-the-art vegetation-rendering program with a library of tree files applicable to a variety of geographical areas. Other CREATION scene-rendering methodologies discussed include efficient ground-texturing techniques and the vegetation model.

Introduction

The objective of the CREATION scene-generation program is to simulate realistic, multispectral, three-dimensional scenes (e.g., IR, visible) of a wide variety of geographical locations and environmental conditions. This capability will reduce the US Army's dependence on actual field data-collection activities by providing a verified/validated synthetic scene-generation methodology that can be used to supplement real data for many applications. Some of these applications include the development, testing, and evaluation of automatic target recognize (ATR) algorithms, image-clutter metrics research, signature phenomenology research, mission planning, training, human perception study, and multispectral-sensor modeling.

General Design of CREATION

The CREATION simulation model consists of several programs developed in-house that integrate/ interface various target geometry, terrain data, and thermal-prediction model outputs into an extremely powerful research tool. The internally developed software includes the Feature Editor, the CREATION scene generator program (graphics user interface, vegetation model, surface-texturing process, and atmospheric and sensor-simulation models). The relationship of CREATION to other models is shown in figure 1.

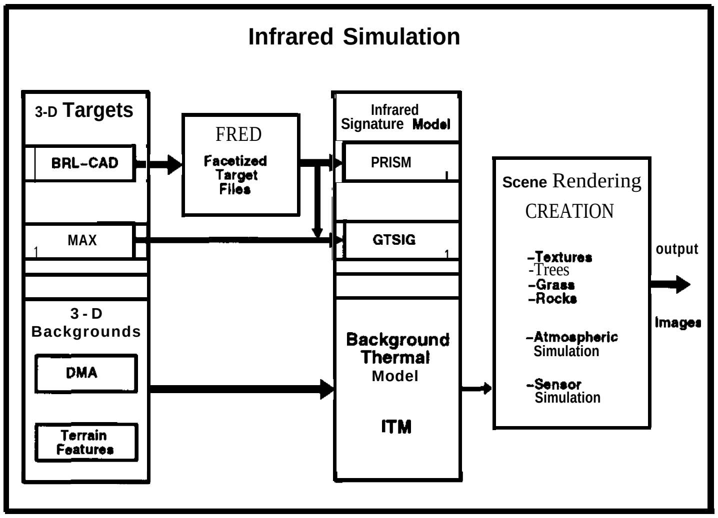


Figure 1. Overview of CREATION scene generation process.

External Models/Input Databases

Generally, CREATION requires existing, externally generated data files to create simulations of specific locations and scenarios. The following data are produced by other programs and processes.

(1) Digital terrain elevation data (DTED) is the standard, digitally formatted DMA-surveyed data that consists of an array of elevation samples at either 100-meter or 30-meter intervals.

(2) Target geometry files are either (a) Ballistic Research Laboratory computer assisted design (BRL-CAD) combinatorial solid geometry (CSG) files that are converted to faceted geometry via the Faceted Region EDitor (FRED) from the Tank Automotive Command Research, Development, and Engineering Center (TARDEC), or (b) MAXCAD-faceted geometry from the Georgia Technological Research Institute (GTRI).

(3) Target-thermal prediction output files are generated using either (a) the Physically Reasonable Infrared Signature Model (PRISM) via FRED, or (b) GTSIG with MAXCAD target geometric input data files. The thermal-prediction files must be generated consistent with the desired scenario (i.e., the physical location, target operating state (e.g., velocity, orientation), and meteorological conditions) to realistically simulate the temperature profile.

(4) Background thermal-prediction output files are created using the Interim Thermal Model (ITM) from the Smart Weapons Operability Enhancement (SWOE) program/Waterways Experiment Station (WES). This model uses meteorological data to predict the temperature profiles of vegetation, roads, and soil surfaces

Internally Generated Data

The location and type of the sensor, types of vegetation present, locations of roads, bodies of water, and the like must be specified to simulate realistic scenarios. The following files are alternatively generated or edited in the CREATION program, or in CREATION's Feature EDitor (FED):

(1) Feature maps are rasterized representations of the data necessary to define the scene content with respect to vegetation, soil, rocks, roads, and bodies of water in the final DMA DTED-mapped area.

(2) Color-spectral files are required for image synthesis. The inputs describe color and lighting model parameters (e.g. ambient light, diffuse light, specular light, and highlighting) for the principal background and target components, exclusive of the trees. The emissivities and reflectivities in the 3-5 and 8-12 μ bands are also defined.

(3) Object-attribute files describe munitions, targets, and nonsolar light sources. These files specify the following: (a) target geometry, (b) target thermal prediction, (c) target camouflage pattern, and (d) target position(s). The target-position file specifies the target's orientation with respect to each of its six degrees of freedom in time. The positions/orientations of munitions and up to seven independent, nonsolar light sources are similarly specified. The munitions are defined according to the COMBIC obscurant model types. The RGB specifications of each munition's smoke and the independent-light- source colors are defined in the object-attribute files, along with general lighting characteristics for movable point sources and spotlights.

(4) Target-camouflage patterns may either be selected predefine visible camouflage patterns or user-created patterns.

(5) The camera sensor-position file is analogous to the position file for the target. The sensor's position, orientation, and its field of view determine what will be seen at any instant.

(6) Input into the atmospheric-transmission parameter file controls atmospheric transmission effects through specification of properties such as humidity, rate of precipitation, reference altitude, and wavelength limits. These internal, atmospheric-transmission model inputs can be either empirical or modeled, using a variety of other atmospheric-transmission models (e.g., LOWTRAN, MODTRAN, or HITRAN).

(7) Sensor-simulation data files consist of several pre-existing sensor files; if they don't contain the pre-existing files, the user may create new sensor-simulation data files by following the recommendations and specifications described in the user's manual. [1]

CREATION Models and Processes

Tree Geometry Model

For realistic high-resolution rendering of natural backgrounds, an accurate representation of vegetation geometry is needed, especially for trees. An algorithmic method of generating tree geometries using a compact parametric description set is preferable to simulate many separate species, and variations of each species. The model should render realistic trees efficiently, so that a large number of individual trees can be included in the background scene. The CREATION tree model [2] meets these criteria by adopting a rule-based methodology that divides the branching levels into structural hierarchies from the main trunk to the smallest branches and leaves. Each level has its own set of specifications and subsequent variational limits to permit the variability of structures found in nature, and to allow the same software code to generate a wide variety of different tree species geometries (see Figure 2). The parameter set is based on basic geometric observable, such as, trunk and branch lengths, cross-sectional ratios, and branching angles. The schematic diagram, Figure 3, shows the basic design concept.

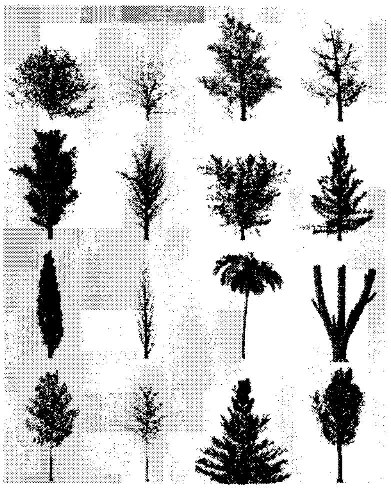


Figure 2. Sample of synthetic trees.

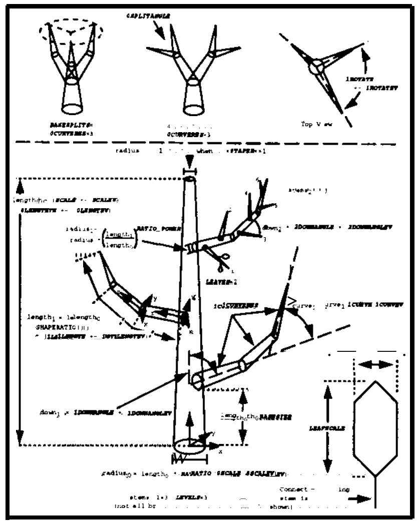


Figure 3. Schematic tree diagram.

Feature Editor

The tree model uses a range-degradation methodology that reinterprets the geometrical description of the tree to substitute fewer lines and points for polygons as range increases and the need for high-resolution rendering is relaxed. This process is performed gradually, so that it is seamless and virtually undetectable, while greatly decreasing the drawing time per tree at longer ranges. This feature is, of course, extremely important for rendering massed trees in a forest for an animation consisting of thousands of frames.

An important part of the CREATION scene-generation package is the feature editor, FED. It enables modelers to create and edit rasterized maps used as input by the rendering software. FED is essentially a specialized multilayer drawing program, with a user-friendly interface to aid the bit-wise manipulation of the resolution-cell data. For instance, the bit-pattern toggle buttons for the vegetation feature map activate 1 of 3 possible kinds of grass and as many as 14 tree types, simultaneously. The road, water, and soil feature maps are similarly specified. This feature-mapping capability permits high-resolution, controlled rendering of realistically cluttered generic or actual natural backgrounds.

The feature editor can overlay multiple digital maps as semitransparencies with perfect coregistration of the rasterized data. It also permits the use of top-down aerial photographs or satellite imagery as templates to create accurate cultural-feature maps (e.g., roads, bodies of water, vegetation) that can closely approximate actual locations, when the necessary supporting data (e.g., road maps, vegetation present, soil properties) are available.

Ground-Surface Texturing

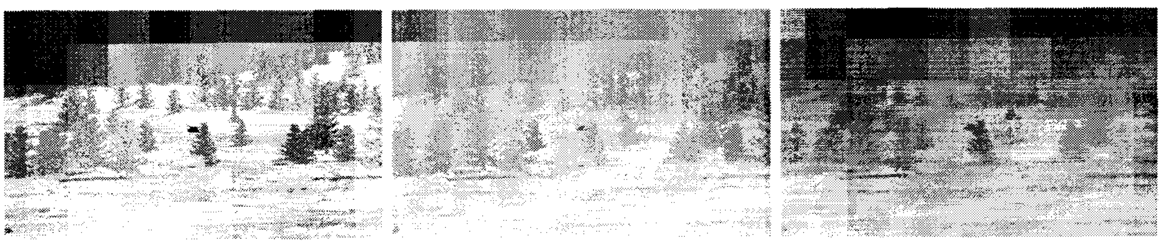
The CREATION texture-mappmg process produces surface-conforming coarse, fine, and very fine textural effects. These effects include vegetation shadows, road surfaces. soil maps, simplified water waves, and topographically specific gullying. Vegetative ground cover variations are applied to the surface texture map, according to vegetation feature-map location and defined or modeled characteristics (e.g., the general color or temperature of each grass type). Individual grass blades are drawn when image resolution and fidelity require that application.

Texture mapping proceeds in four basic stages: (1) ground-surface texture differences, (2) erosive effects (gullying) that are dependent on the local-terrain-surface gradient, (3) tree shadows drawn according to solar inclination and azimuth angles, and (4) vegetative ground texturing to modulate assigned grass colors or temperatures, and to characterize the grass surfaces at ranges where resolution is so good that it diminishes the necessity to render individual grass blades.

Ground-surface texturing is, itself, a multistage investigative technique, consisting of: (1) finding gross surface texture over the entire area, (2) applying fine texture with 16 times the resolution of the gross surface texture map, and (3) applying very fine texture covering the same area as the fine texture, but adding bounded Gaussian random noise to diminish the pattern repetition that would otherwise be obvious over larger areas. The patterns of gross and fine texture are generated using a growth-rule algorithm that is conceptually similar to the propagation of bacterial colonies in a culture medium.

Atmospheric Transmission and Battlespace Obscurants

The CREATION simulation package has a computationally efficient, simplified LOWTRAN-equivalent atmospheric transmission model for the visible and infrared spectral bands that applies attenuation and scattering effects, with input parameters that correspond to empirical meteorological data [3]. The atmospheric model also predicts altitude-dependent background sky-radiance effects. Other models (e.g., LOWTRAN, MODTRAN, HITRAN) can use the image and range-buffer output for post-processing atmospheric effects. Figure 4 shows (a) an input image, with (b) a foggy atmosphere applied, followed by (c) the application of sensor effects to the image.



(a) (b) (c)

Figure 4. Input image (a), with atmosphere applied (b), and with sensor applied (c).

The CREATION model also has a menu interface to define, locate, and set detonation or ignition times of munitions or fires; set wind velocities; and then process visible battlespace obscurants using the COMBICV model.

Sensor, Optics, and Noise Modeling

CREATION scene-generation software is a powerful sensor simulation model that uses a super-set of the FLIR92 sensor parameters and specifications to emulate the performance of a large variety of existing and proto-typical thermal and visible sensor systems [1] [4]. The model simulates optical blurring effects, including depth-of-field or focus, that vary according to aperture size, range-to-pixel, and position on the image plane, in addition to other optical aberrations. Sensor-sampling effects are modeled when processing high-resolution images (i.e., more than one pixel-per-detector instantaneous-field-of-view (IFOV)). Noise, particularly Gaussian-shot noise, various detector nonuniformities and nonlinearities, and sensor- scanning and -sampling artifacts, are added in thermal sensor simulations. This model can easily emulate the effects seen (especially) in older first-generation forward-looking infrared (FLIR) systems, as well as those seen in more advanced systems. Of course, other sensor models can be used to post-process stored output imagery.

Conclusion

The integrated and coordinated scenarios that are simulated with CREATION can be useful for a wide range of applications relevant to battlespace flight scenarios (either as attacker or defender), as well as surface warfare. Applying our simulation methodology, a defense modeler can model aerial attacks from fixed- or rotary-wing aircraft in various realistic weather conditions, using modeled visual- and thermal-sensor systems, and also produce geometric facet data for input into advanced radar models. The study of the effects of factors such as weather, sensors, and obscurants, on mission effectiveness can be made by relatively simple changes to the appropriate model inputs, without altering the majority of the files in the scenario database. Very accurate mission-specific simulations can be modeled when the supporting modeling tools or outputs are made available. If self-consistent input data are entered into the external-prediction models, accurate, high-fidelity, high-resolution output imagery and output geometrical representations will be generated by CREATION. These simulations have many applications, including training and mission planning, as well as scientific research, engineering development, and testing of ATR algorithms, human perception, multispectral sensor modeling, and others.

References

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Proceedings of SPIE (Society of Photo-Optical Instrumentation Engineers), April, 1993.

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Mr. Charles R. "Chuck" Kohler was born in New York City and received a Master of Science degree from Cornell University, Ithaca, New York in Engineering Physics and Mathematics. He was commissioned a 2ND Lieutenant, Infantry, in the US Army and spent about 3 years on active duty in Germany. He is "Airborne" and "Special Forces" Qualified, a Vietnam Era Veteran, and currently a member of the US Army Ready Reserves. He has over 38 years of federal service and was recently selected by the Department of the Army to be a Judge at the International Science and Engineering Fair. He has a keen interest in simulating science and engineering education among American youth. He has been an outstanding volunteer judge at many science fairs in the past. His current interest is in modeling, simulation, and synthetic imagery.

Mr. Hung M. Nguyen was born in Vientiane, Laos. He received his BSEE from the University of Bordeaux, France and his M.S. in Electronics and Computer Engineering from the George Mason University. He has been with the Night Vision and Electro-Optics Laboratory since 1989 and joined the U.S. Army Research Laboratory in 1992 where he works on thermal and radar signature modeling, FLIR sensor simulation, and computer scene simulation. He is currently the project leader of the Multispectral scene generation program. Mr. Nguyen has numerous publications in the area of Radar signature modeling and Infrared computer scene simulation.

Mr. Joseph A. Penn was born in Easton, Maryland on November 11, 1949. He graduated in May, 1984 with a Bachelors Degree in Physics and Chemistry from *Millersville University of Pennsylvania*, Millersville, PA. Prior to entering college, Mr. Penn worked for eight years as a landscape artist. He has been employed by the U.S. Army Research Laboratory (ARL) for three years and for the last twelve years has worked for the Army on various aspects of physical and geometric modeling in the thermal and visible spectral domains. Mr. Penn developed algorithms for vegetation geometry and surface texturing that are included in ARL's CREATION scene modeling software.

Mr. Marcos C. Sola is the technical leader of the Modeling Validation Group in the Synthetic Image Branch of the U.S. Army Research Laboratory in Adelphi, Maryland. His research interests include synthetic signal validation, modeling of target signatures and of atmospheric effects on multispectral electromagnetic wave propagation, and systems performance analysis. In addition to his current position, Mr. Sola's career has included work as Technology Associate for Signatures for the Sensors, Signatures, and Signal Processing Office, Project Leader for the Survivability and Management Office, the CM/CCM Office, and the Night Vision and Electro-optics Laboratory in Fort Belvoir Virginia. Mr. Sola holds B.S. and M.A. degrees in Physics from American University, has received numerous U.S. Army Achievement Awards, and publishes extensively.